National Park Service
U.S. Department of the Interior

Geologic Resources Division

U. S. National Park Service Geology

Inventory and Assessment Efforts:

The NPS Geologic Resources Inventory

America's Geologic Heritage Invitational Workshop
Denver, Colorado USA
March 18-19, 2013

Topics for Discussion

- Present methodologies used to inventory & assess geologic heritage area, landscapes and features
- Identify gaps in current inventory & assessment efforts hindering geologic heritage program
- Connections between inventory & assessment, sustainability & stewardship, museums / collections, and education / outreach

Acadia NP, Maine

Why a Geologic Resources Inventory (GRI)?

- NPS Natural Resource Challenge
  - Geologic map is one of 12 basic inventories
  - Science-based park resource management
- NPS Strategic Plan goal 1b1: Natrual Resource Inventories
  - Identified "digital geologic maps" as a needed data set
- NPS 75: "Inventory and Monitoring Guideline"
  - Digital geology maps ("bedrock" / surficial)
  - Special purpose maps (geohazards, coastal)

Why a GRI? (Continued)

- Every park has geology !
- Not every park has a geologist

Hawaii Volcanoes NP, Hawaii

Kings Mountain NMP, South Carolina

EXPERIENCE YOUR AMERICA

Partnerships are integral to accomplish work of the NPS GRI

Colorado State University

USGS
science for a changing world

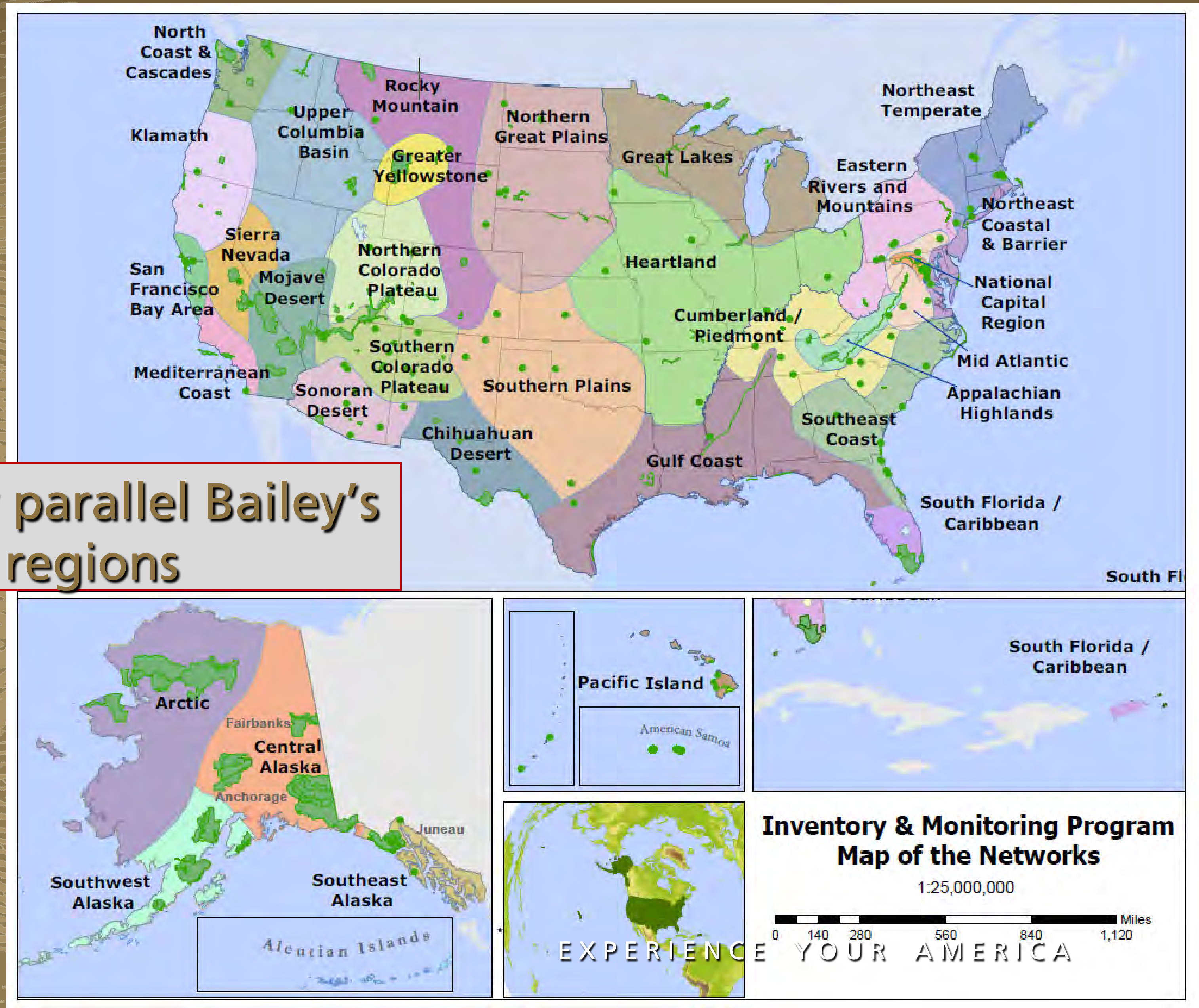
AASG
Association of American State Geologists

THE GEOLOGICAL SOCIETY OF AMERICA®

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

AGI
SERVING THE GEOSCIENCES
1948

NPS Inventory & Monitoring Networks



- 32; Closely parallel Bailey's ecosystem regions

GRI Goals

For each of "270*" NPS units,
deemed to have "*significant natural resources*"

- An on-site scoping meeting
- A digital geologic map
- A geologic report

* NOTE: there are 398 official NPS units

GRI Goals (continued)

- Realized that just a map is not helpful
- Scoping meeting summary
- Digital geologic map
  - GIS-geology data (currently ESRI ArcGIS 10.1)
  - Guide for using GIS data
  - ArcGIS geologic map document (.mxd)
  - NPS geologic map GIS data model
- Hardcopy report (follows completion of geologic map)
  - Geologic issues, features and processes, geologic history
  - Map unit properties table (MUPT)
  - Overview of geologic map data

GRI Goal #1: Scoping Summary

- Summarizes meeting discussions
- Basis for mapping plan and report process
- provides participants / important contacts list
- Interim product until full-blown report is completed

Geologic Resources Inventory Scoping Summary
Sleeping Bear Dunes National Lakeshore
Michigan

Prepared by Katie KellerLynn
December 10, 2010

Geologic Resources Division
National Park Service
U.S. Department of the Interior

The Geologic Resources Inventory (GRI) Program provides each of the 270 identified natural area National Park System units with a geologic scoping meeting and summary, a digital geologic map, and a geologic resources inventory report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues and, if possible, include a site visit with local experts. Meeting discussions also highlight distinctive geologic features and processes and identify potential mapping, monitoring, and research needs.

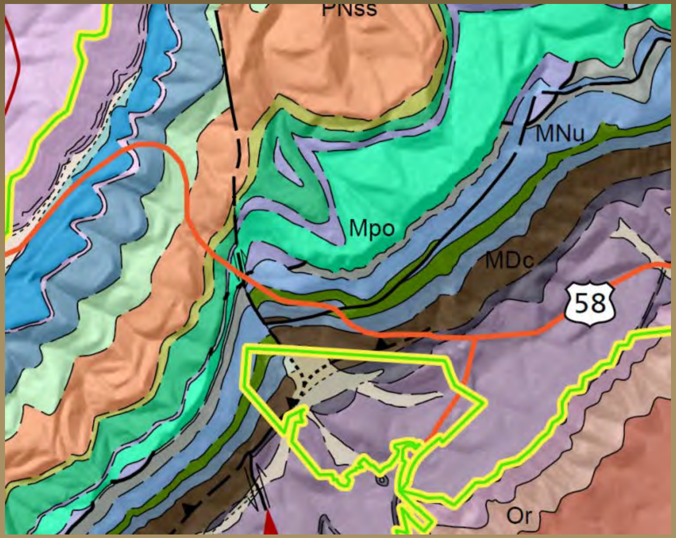
The National Park Service (NPS) Geologic Resources Division held a GRI scoping meeting for Sleeping Bear Dunes National Lakeshore on June 30, 2010, at the park headquarters in Empire, Michigan. Participants at the meeting included NPS staff from the national lakeshore and Geologic Resources Division, and cooperators from Colorado State University, Grand Traverse Band of Ottawa and Chippewa Indians, Indiana Geological Survey, Michigan Department of National Resources and Environment (MDNRE) Office of Geological Survey, Michigan State University, Northwestern Michigan College, and the U.S. Geological Survey (see table 6). Superintendent Dusty Shultz welcomed the group and expressed her support of the Geologic Resources Inventory, stating "geology is a critical component of our resources." Chief of Natural Resources Steve Yancho provided background information on the natural resources of Sleeping Bear Dunes, and Facility Manager Lee Jameson covered cultural resources. During the "geologic overview" portion of the agenda, Kevin Kincare (U.S. Geological Survey) highlighted many of the glacial features and other landforms at the national lakeshore. Todd Thompson (Indiana Geological Survey) made a presentation about the evolution of the shoreline-dune system surrounding Lake Michigan and briefly discussed isostatic rebound and the vibracore method of taking sediment samples in the vicinity of Lake Michigan. Frank Snyder (Northwestern Michigan College) provided information about dune stabilization and the significance of paleosols within the dunes. Georgia Hybels (Geologic Resources Division) facilitated the group's assessment of map coverage and needs, and Lisa Norby (Geologic Resources Division) led the discussion of geologic features, processes, and issues.

During the site visit on the afternoon of June 30, participants drove to Miller Hill, which serves as an overlook for Glen Lake, the Manistee moraine, beach ridges, dunes, Sleeping Bear Point, and Lake Michigan. This stop highlighted a combination of glacial and shoreline features. Miller Hill is composed of ice-marginal debris. The second stop was the Dune Climb, which the National Park Service manages as a "sacrifice dune," allowing visitors to climb to the top. From the top of the dune, it appears an easy walk to Lake Michigan, but the lake's waters are actually 3 km (2 mi) away. Baby's breath (*Gypsophila paniculata* L.), a nonnative invasive species, covers much of this highly popular area. After visiting the Dune Climb, scoping participants drove the Pierce Stocking Scenic Drive, making stops at the Dune and Lake Michigan overlooks. These stops provided an opportunity to discuss shoaling at North Manitou Island, the creation of social trails on dunes, the "ghost forests" buried in sand, maintenance of windblown sand on anthropogenic structures (i.e.,

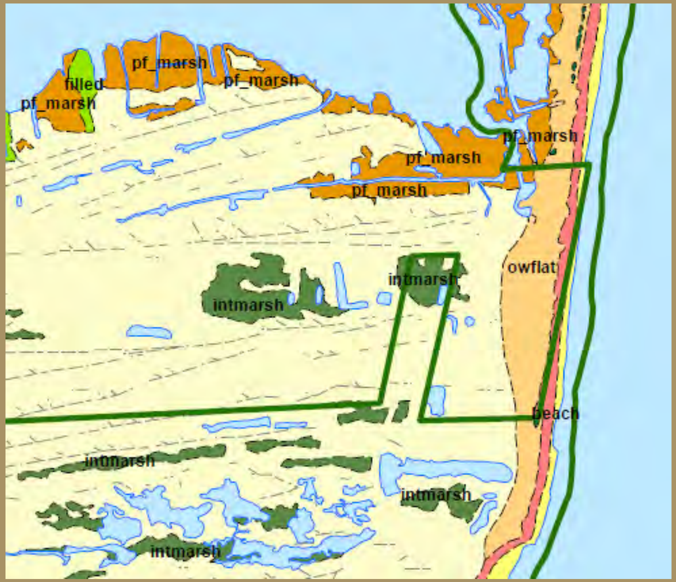
Scoping Summary

GRI Goal # 2: Geologic Map

- Shows location of geologic materials (rocks / deposits); i.e. Bedrock and surficial geology
- Structures (folds, faults)
- Attitude / observation points
- Hazards
- Glacial features
- Adapt with every new map in every geologic terrane

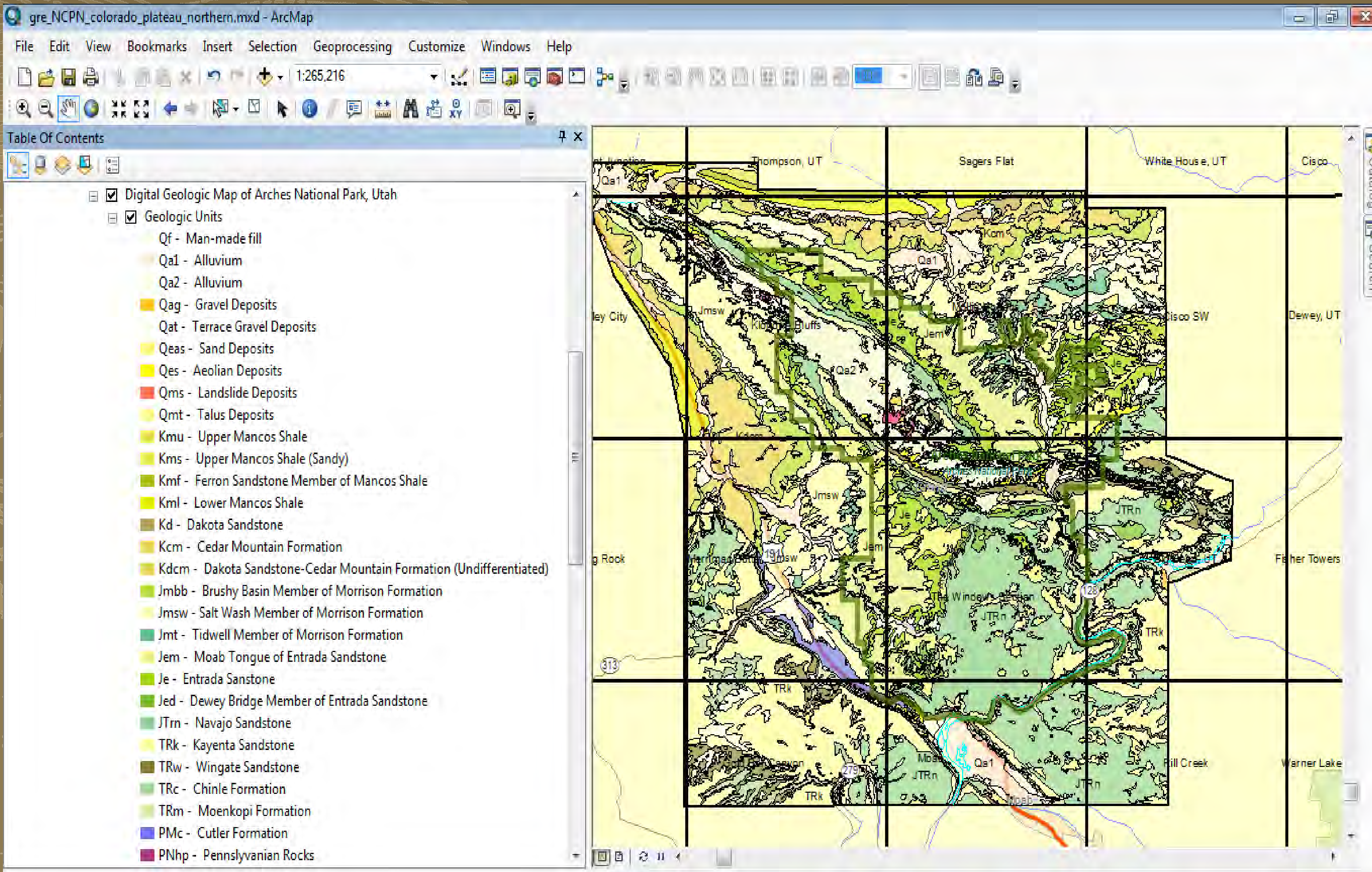


Cumberland Gap NHP, VA, TN, KY

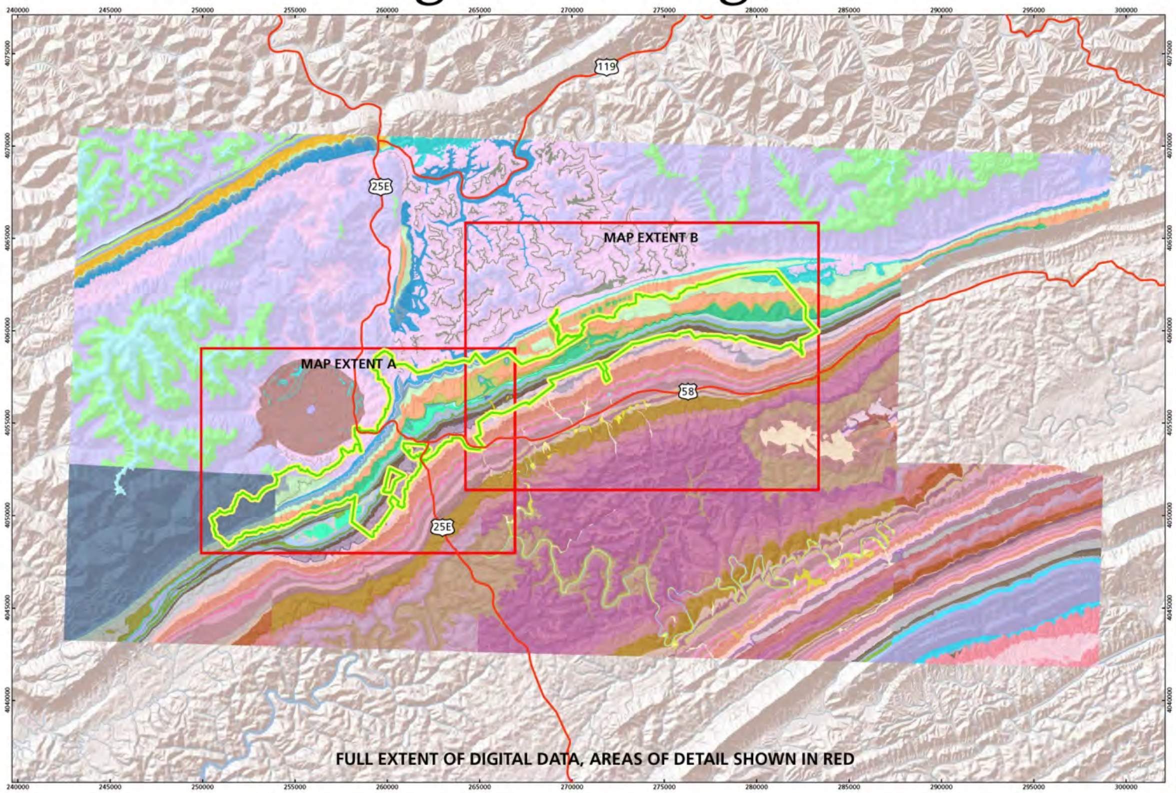


Cape Hatteras NS, North Carolina

GRI Digital Geologic Map of Arches NP



Overview of Digital Geologic Data for Cumberland Gap NHP



UTM Zone 17N NAD 83
scale greater than source data

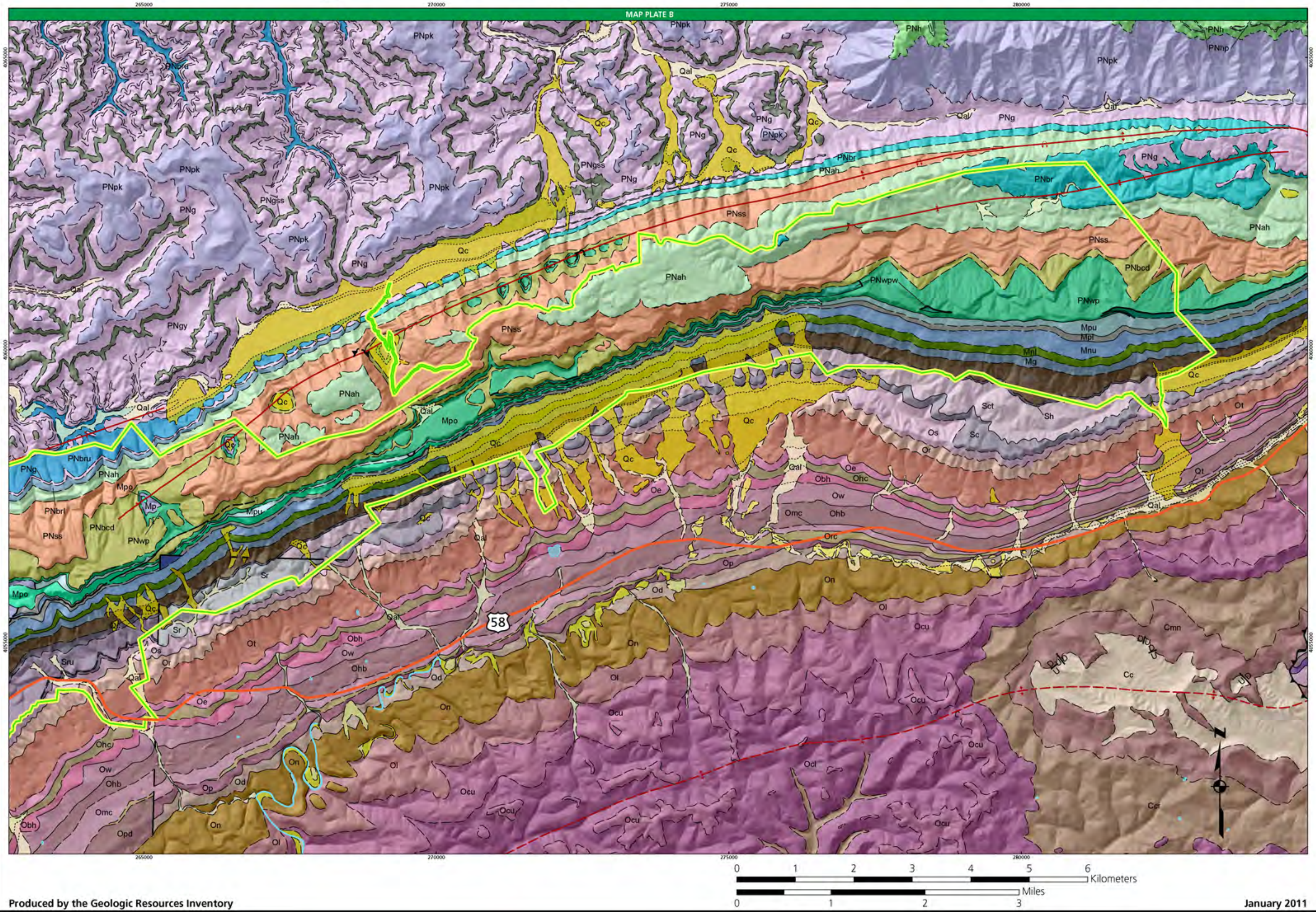
Produced by the Geologic Resources Inventory

January 2011

Cumberland Gap National Historical Park
Kentucky, Tennessee, Virginia

National Park Service
U.S. Department of the Interior

Overview of Digital Geologic Data for Cumberland Gap NHP

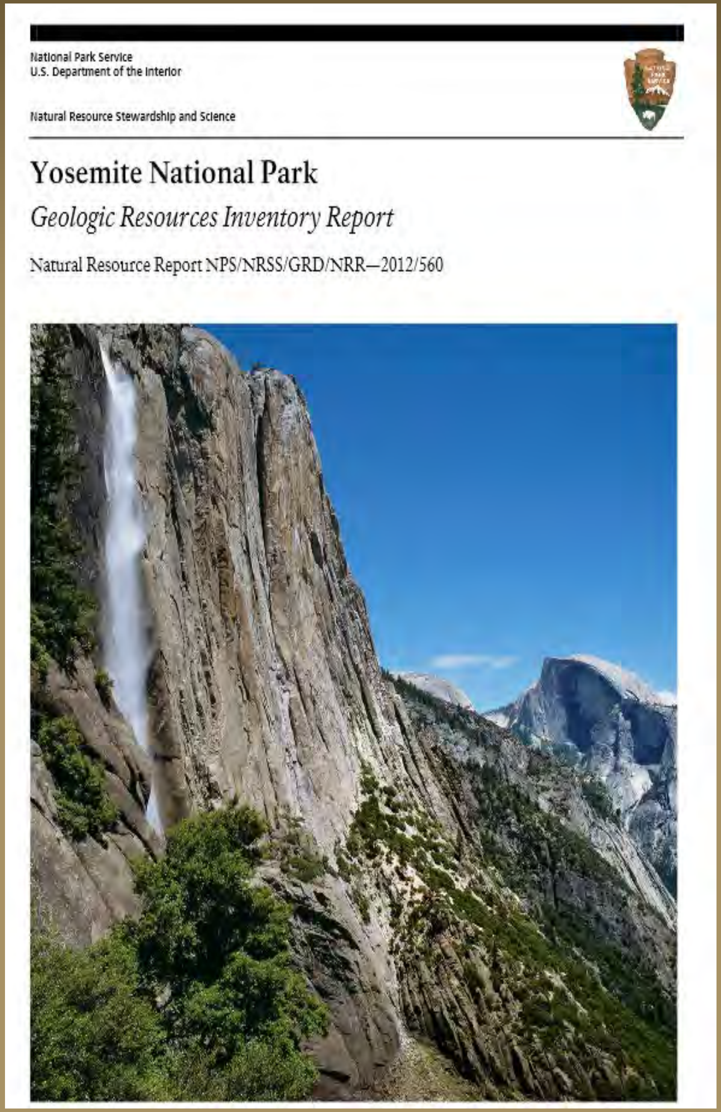


Produced by the Geologic Resources Inventory

January 2011

GRI Goal # 3: GRI Report

- Links the map and park manager to park's geologic landscape
- Accessible to non-geologists
- Park-specific
  - Geologic Issues
  - Geologic Features and Processes
  - Geologic History
- Make connection to map
  - Map Unit Properties Table
  - Overview Graphic



Geologic Features and Processes

- Windblown (aeolian)
- Cave/karst
- Coastal
- Stream (fluvial)
- Marine or lake (lacustrine)
- Geothermal
- Glaciers
- Permafrost
- Fossils
- Seismic
- Mass Wasting
- Volcanoes

Abraham Lincoln Birthplace NHP, Kentucky

Fossil Butte NM, Wyoming

Rainbow Bridge NM, Utah

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Natural Resource Stewardship and Science

Yosemite National Park

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2012/560

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Map Unit Properties Table (MUPT)

making the crosswalk from map to reality

Map Unit Properties Table A: Compiled Bedrock and Surficial Map, Yosemite National Park

Gray-shaded rows indicate units not mapped within the park. Bold text corresponds to sections of the report. Colors in Map Unit columns correspond to Geologic Map Overview sheets 1 (simplified map, entire park) and 2 (detailed map, Yosemite Valley).

Age	Simplified Map Unit (Symbol) Overview Sheet 1		Map Unit (Symbol) Colored if present on Overview Sheet 2	Geologic Description	Geologic Issues	Geologic Features, Processes and General Location	Geologic History
Quaternary Surface and Glacial Rock Units							
QUATERNARY (Holocene)	Alluvium (Qal)		Alluvium (Qal)	Primarily gravel, sand, and silt that underlies meadows. Deposited by streams.	**Debris Flow and Flooding**—Overbank and floodplain deposits represent flood and debris-flow events.	**Recent Geomorphic Features (Fluvial)**—Meandering channel patterns, point bars, cutbanks, terraces, floodplains, and debris deposited during flooding.	These unconsolidated units in Yosemite National Park represent flooding and mass-wasting processes that have occurred throughout geologic time (principle of uniformity). Geologists study these recent deposits to better understand ancient depositional environments and their associated geologic units.
QUATERNARY (Holocene)	Talus (Qt)		Talus (Qt)	Rock debris derived from cliffs. Talus piles are present at most cliff bases, especially in Yosemite Valley.	**Rockfalls, Rockslides and Rock Avalanches**—These mass-wasting deposits represent unpredictable movement of rock material from unstable slopes. They are hazards that affect visitor safety and park infrastructure (i.e., roads, trails, buildings, sewer lines, campgrounds). Triggering mechanisms vary. **Erosion**—Slopewash involves the transportation of rock and soil down a slope by rain. In general, slopewash presents a smaller hazard than rockfall.	**Talus Piles**—Large talus piles have formed beneath cliffs that contain abundant joints, such as The Rockslides (west of El Capitan).	
QUATERNARY (Holocene)	Talus and Slopewash (Qts)		Talus and Slopewash (Qts)	Unconsolidated mixture of debris (soil and rocks) that may be washed down slopes by running water not confined to channels.		**Talus Piles**—Primarily mapped in the Hetch Hetchy Reservoir quadrangle in the park. May contain abundant volcanic pumice.	
QUATERNARY (Holocene)	Landslide (Qls)		Landslide (Qls)	Unsorted debris deposits resulting from mass movement.		**Landslides**—Includes inactive rock glaciers. The unit is mapped primarily in the northern part of the park.	
QUATERNARY (Holocene)	[illegible]	Glacial Units	Neoglacial and periglacial deposits (Qng)	Angular rock debris and talus with particle sizes ranging from sand to cobbles and boulders of 3 m (10 ft) or more from existing Holocene glaciers (neoglacial). Includes deposits in glacial features that form along the margins of existing glaciers or former post-Pleistocene glaciers (periglacial).	**Erosion**—Glacial deposits may form unstable slopes.	**Modern Glacial Features**—Exposed in the northern and eastern parts of the park in the Tower Peak, Matterhorn Peak, and Mono Craters quadrangles.	**Tension, Uplift, and Ice**—Present-day glaciers began forming about 500 years ago. The deposits reflect changing climatic conditions that are melting the glaciers.
QUATERNARY (Holocene)		Glacial Units	Rock glaciers (Qrg)	Poorly sorted angular boulders and fine material with interstitial ice about 1 m (3.3 ft) below the surface.	None—Rock glaciers move slowly and are not a geologic issue.	**Modern Glacial Features**—Isolated deposits of limited areal extent exposed east of the eastern park boundary in the Mono Craters quadrangle.	**Tension, Uplift, and Ice**—Isolated deposits. Larger, mappable exposures lie east of the park.
QUATERNARY (Pleistocene)	Lake beds (Qlk)	Glacial Units	Lake beds (Qlk)	The source map does not provide a detailed description.	None—This unit lies outside of the park boundaries.	**Geomorphic Feature**—Borders the western edge of Mono Lake in the Mono Craters quadrangle.	**Tension, Uplift, and Ice**—Remnants of a large lake in the Mono Basin fed by Pleistocene glaciers.
QUATERNARY (Pleistocene)	[illegible]	Glacial Units	Glacial deposits (Qg)	Primarily unconsolidated moraine and outwash deposits. Includes Tioga and Tahoe till.	None Significant	**Pleistocene Glacial Features (Depositional)**—Moraines	**Tension, Uplift, and Ice**—Late Pleistocene glacial deposits.
QUATERNARY (Pleistocene)	Tills (Qti)	Glacial Units	Tioga Till (Qti)	Unsorted till deposits. All granitic, volcanic, and metamorphic rocks are relatively fresh.	**Flooding**—Qti forms the El Capitan moraine in Yosemite Valley and may act as a natural dam during spring flooding of the Merced River.	**Pleistocene Glacial Features (Depositional)**—Sharp-crested moraines, usually with abundant boulders on the surface.	**Tension, Uplift, and Ice**—Tioga-age (26,000–18,000 years ago) glacial deposits.

Yosemite NP MUPT

Age	Simplified Map Unit (Symbol) *Overview Sheet 1*	Map Unit (Symbol) *Colored if present on Overview Sheet 2*	Geologic Description	Geologic Issues	Geologic Features, Processes and General Location
CRETACEOUS (Upper)	Tuolumne Intrusive Suite (Ktu)	Half Dome Granodiorite (Khd)	Light-colored, medium- to coarse-grained, massive, equigranular hornblende-biotite granodiorite. Contains large crystals of potassium and plagioclase feldspar, biotite, hornblende, and honey-colored sphene up to 10 mm (0.4 in) wide and phenocrysts of potassium feldspar up to 3 cm (1.2 in) wide. Spaces between these crystals are filled by quartz. May be divided into: 1) a porphyritic phase (Khdp) with potassium-feldspar megacrysts commonly slightly more than 1 cm (0.4 in) wide and 2–3 cm (0.8–1.2 in) long, and 2) a medium-grained equigranular phase (Khde) characterized by euhedral hornblende prisms 1–3 cm (0.4–1.2 in) long, biotite books up to 1 cm (0.4 in) wide, and conspicuous sphene.	**Rockfalls**—Previous rockfalls from Ahwiyah Point have buried part of the Mirror Lake Loop Trail and damaged the Ahwahnee Hotel.	**Granitic Bedrock**—Forms Half Dome and the sheer cliffs between the Ahwahnee Hotel and Mirror Lake. Good exposures at Olmsted Point and along the trail to Vernal and Nevada falls. **Splitter cracks**—A notable climbing route is "Sons of Yesterday" near Royal Arches beneath North Dome. **Flakes**—A notable climbing route is "Hermaphrodite Flake" on Stately Pleasure Dome above Tenaya Lake. **Dihedrals**—A notable climbing route is "Great White Book" on Stately Pleasure Dome above Tenaya Lake. **Dikes**—A notable climbing route is "Snake Dike" climb on the southwest face of Half Dome. **Slabs**—Popular slab climbs on the Glacier Point Apron include "Marginal," "Goodrich Pinnacle," and "The Cow". **Joints**—Exfoliation joints are the primary joint type responsible for the famous landmark Half Dome.
		Granite of Marie Lakes (Kma)	Light-gray, fine-grained biotite granite.	None Significant—Dikes (linear features) pose little potential for significant geologic issues in the park.	**Granitic Bedrock**—Exposed in dikes near Marie Lakes and on the south slopes of Mounts Lyell and Maclure the Merced Peak quadrangle.
		Granodiorite of Grayling Lake (Kgrl)	Fine- to medium-grained, well-foliated biotite-hornblende granodiorite. Contains 20–25% small anhedral (lacking well-developed crystal faces) grains of biotite and hornblende and relatively abundant sphene.	None Significant—Limited areal extent on relatively gentle slopes. Little potential for significant geologic issues.	**Granitic Bedrock**—Exposed along the west side of the Clark Range in the Merced Peak quadrangle.
		Granodiorite of Glacier Point (Kglp)	Dark, medium-grained, equigranular well-foliated granodiorite, tonalite, and quartz diorite containing abundant small dark inclusions. Typically contains 15–25% subequal biotite and hornblende. Biotite and hornblende may occur as anhedral grains or in clusters 1–5 mm (0.04–0.2 in) wide. Some grains contain augite.	**Rockfalls**—Rockfalls in 2008 impacted the historic Curry Village area.	**Granitic Bedrock**—Forms a band west of the Half Dome Granodiorite in the Yosemite quadrangle. **Splitter Cracks**—A notable climb is "The Grack" below Glacier Point.
		Tonalite of Glen Aulin (Kgla)	Dark-colored rock of variable composition ranging from fine-grained quartz diorite in the west to medium-grained granodiorite at the eastern contact with Khd and Kcp.	**Rockfalls**—Potential issues for areas north and south of the Glen Aulin High Sierra Camp, but relatively gentle slopes near the camp.	**Granitic Bedrock**—Exposed in the Tuolumne Meadows quadrangle.
		Granodiorite of Kuna Crest (Kkc)	Dark-colored, medium-grained, hornblende-biotite granodiorite. Crystals are smaller and biotite and hornblende more abundant than in some other granitic rocks in the park. May contain 20–25% anhedral biotite and hornblende. Contains abundant dark phenocrysts of plagioclase and biotite.	**Rockfalls**—Potential on steeper slopes. Exposed near Tioga Pass but well away from the road. Exposures primarily in the backcountry.	**Granitic Bedrock**—Forms the margin of the Tuolumne Intrusive Suite. The unit consists of gray dikes and small intrusive masses with abundant dark phenocrysts on Mt. Lyell, Mt. Maclure, Rodger Peak, and Electra Peak.
		Sentinel Granodiorite (Ks)	Light-colored, medium-grained, equigranular granodiorite and less abundant tonalite, quartz diorite, and granite. Contains inclusions of El Capitan Granite (Kec). Hornblende, biotite, and sphene 2–5 mm (0.08–0.2 in) wide.	**Rockfalls**—From extensive sheet (exfoliation) jointing. Rockfall in 1980 was triggered by an earthquake.	**Granitic Bedrock**—Main mass crosses Yosemite Valley near Sentinel Rock. **Joints**—Exfoliation joints are present.

Map Unit Properties Table

Map Unit Properties Table: Little Bighorn Battlefield National Monument

Colored rows indicate units mapped within Little Bighorn Battlefield National Monument. Colors in Map Unit column correspond to colors on the overview graqphic.

Age	Map Unit (Symbol)	Geologic Description	Geologic Issues	Geologic Features and Processes	Geologic History and Park Connections
QUATERNARY (Holocene)	Alluvium (Qal)	Well to poorly stratified, dominantly clast supported, and moderately well sorted gravel, sand, silt, and clay along active channels of rivers, streams, and tributaries. Includes alluvial terrace deposits less than 1.8 m (6 ft) above river or stream. Thickness as much as 10 m (35 ft).	Channel migration and erosion. Flooding potential. Anthropogenic disturbances—Channel relocation, riprap, channel clearing, diking, bridge abutments, and diversion.	Makes up steep riverbanks. Mineral resources—Sand, gravel, clay, and placer gold.	Impaired troop movements during the battle
QUATERNARY (Holocene and Pleistocene)	Landslide deposits (Qls)	Rock and soil that moved down slope in discrete units through mass-wasting processes that resulted in irregular or hummocky surfaces. Thickness 30 m (100 ft) to 46 m (150 ft).	Potential impacts to infrastructure and human safety.	Potentially unstable deposit prone to future gravity-driven movement.	Mass wasting indicates slope instability sometime during the Holocene (the past 11,700 years)
QUATERNARY (Pleistocene)	Alluvial terrace deposits (Qat)	Gravel, sand, silt, and clay underlying alluvial terrace surfaces adjacent to and higher in elevation than modern streams and rivers. Poorly to moderately well stratified and sorted with planar and trough cross bedding. At least eight distinct terrace levels occur along Little Big Horn River, ranging from 3 m (10 ft) to 170 m (560 ft) above the river. Gravel composed of rounded to subrounded clasts of limestone and dolomite, andesite and other mafic volcanic rocks, as well as quartzite, granitic rocks, sandstone, and chert. Lowest terrace deposit is approximately 20,000 years old; highest is 1.4 million years old (Agard 1989). Thickness 5 m (16 ft) to 15 m (49 ft).	Flooding potential. Erosion potential.	Principal aquifer along the Little Bighorn River. Fossils—Known to contain Pleistocene fossils regionally (e.g., musk ox; see Reheis 1987) Mineral resources—Sand, gravel, and placer gold.	Location of Indian encampment during the battle. Records past floodplain surfaces. Formed during the Pleistocene and range in age from 1.4 million to about 20,000 years old. The wide variety of clasts within the gravels attest to the wide variety of geologic units eroded by the ancient Little Bighorn River.
TERTIARY (Paleocene)	Tullock Member of Fort Union Formation (Tft)	Yellowish-gray, fine- to medium-grained trough cross-bedded, plane-bedded, or massive sandstone. Interbedded with brownish-gray or dark-gray carbonaceous shale (much less abundant than the sandstone). Sandstone beds thinner, more tabular, and persistent than those in underlying Lance Formation. Thickness 70 m (230 ft) to 120 m (395 ft).	Shale may cause slippage. Usually forms steep escarpments. Energy development (unit is source of coal).	Fossils—Freshwater shells, ceratopsian supraorbital bone fragment, and plant fossils (Rogers and Lee 1923). Mineral resources—Coal. Water resources—Aquifer.	Originally deposited in lakes and rivers in a large basin formed during the rise of the Rocky Mountains. The major coal beds of the Fort Union Formaiton, particularly in Wyoming, are deposits of organic material buried in forests within the basin.
UPPER CRETACEOUS	Lance Formation (Kl)	Light brownish-gray, fine-grained, cross-bedded, lenticular-bedded, or massive sandstone. Interbedded with light olive-gray to greenish-gray shale, less abundant than the sandstone. Contains calcite-cemented concretionary sandstone lenses. Sandstone beds thicker and more lenticular than those in overlying Tullock Member. In many areas contains very light-gray, fine- to medium-grained sandstone interbedded with coal in the lower part, with some associated clinker. Thickness 140 m (460 ft) to 160 m (525 ft).	Shale may cause slippage. Energy development (unit is source of coal)	Fossils—Abundant marine fauna (Thom and Dobbin 1924). Shells and leaves (Stone and Calvert 1910). Ceratopsian fossils (Calvert 1912). Marine fossils, plants, and bones of reptiles (turtles and dinosaurs), brackish-water oysters (Lloyd and Hares 1915). Freshwater snails (Rogers and Lee 1923). Extensive vertebrate fauna (amphibians, reptiles, mammals, and fish), gastropods, and pelecypods (Breithaupt 1982). Mineral resources—Coal and gypsum. Water resouces—Fairly good source of water (Thom et al. 1935).	Originally deposited in Cretaceous Interior Seaway, a shallow sea connecting ancient Gulf of Mexico to ancient Arctic Ocean. Brackish-water fossils suggest shallower marine environments, likely near a shoreline.
UPPER CRETACEOUS	Fox Hills Formation (Kfh)	Brownish-gray siltstone and fine-grained cross-bedded or hummocky-bedded poorly resistant sandstone interbedded with dark gray shale. Thickness 30 m (100 ft).	Shale may cause slippage. Forms ledges and cliffs (Shroba and Carrara 1996). Bentonite may cause shrink-swell.	Fossils—Rounded concretions with fossils (Brown 1917). Brackish-water pelecypods (Scott 1963). Foraminifera (Van Horn 1957). Flora and burrows, usually *Ophiomorpha* (Rigby and Rigby 1990). Oyster shells and trace fossils (Roehler 1993). Mineral resources—Bentonite (Obradovich and Cobban 1975).	Originally deposited in Cretaceous Interior Seaway, a shallow sea connecting ancient Gulf of Mexico to ancient Arctic Ocean.

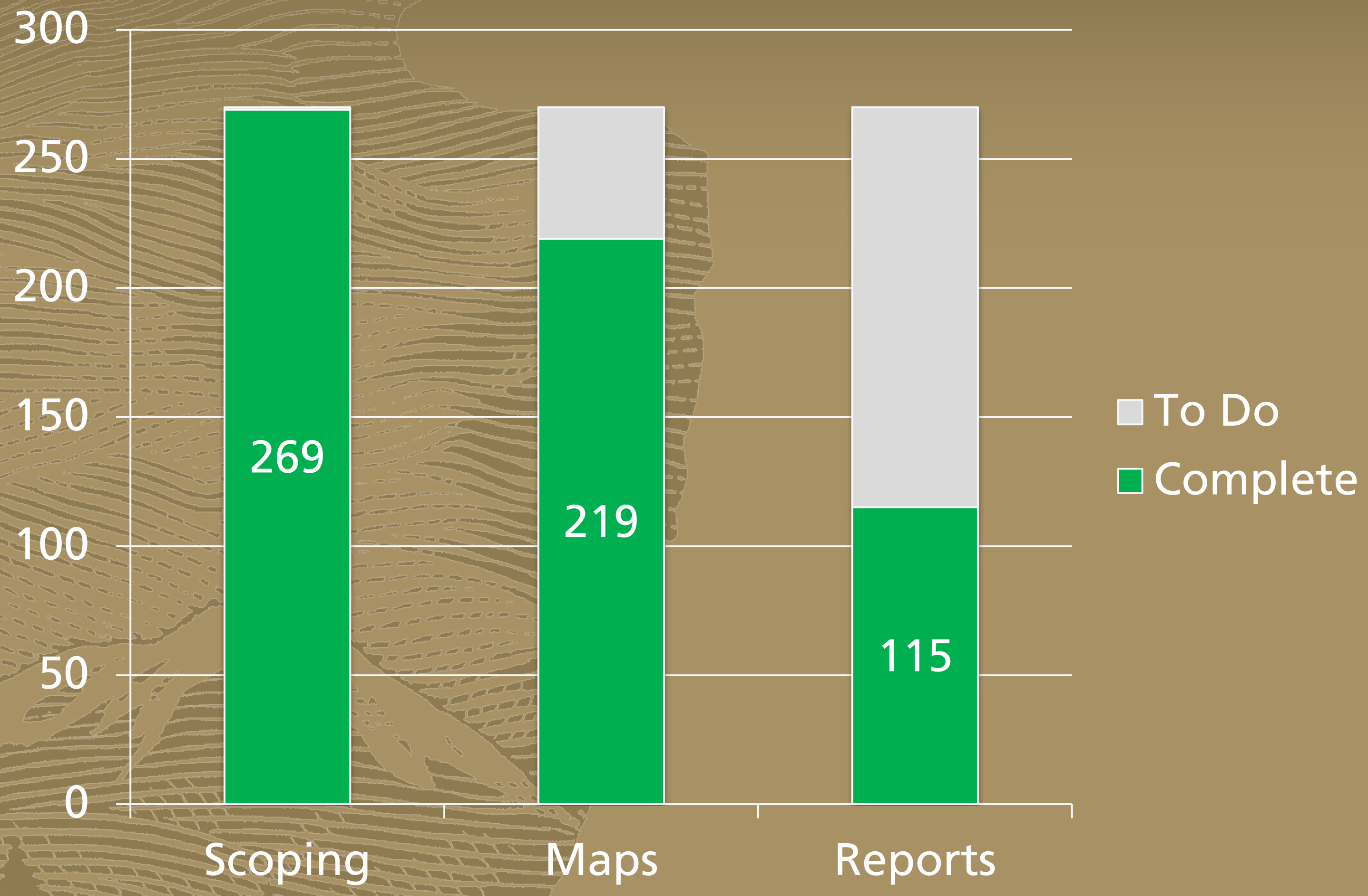
[redacted]

Age	Map Unit (Symbol)	Geologic Description
QUATERNARY (Holocene)	Alluvium (Qal)	Well to poorly stratified, dominantly clast supported, and moderately well sorte sand, silt, and clay along active channels of rivers, streams, and tributaries. Inclu alluvial terrace deposits less than 1.8 m (6 ft) above river or stream. Thickness a as 10 m (35 ft).
QUATERNARY (Holocene and Pleistocene)	Landslide de (Qls)	
QUATERNARY (Pleistocene)	Alluvial ter deposit (Qat)	

Geologic Issues	Ge
Channel migration and erosion. Flooding potential. Anthropogenic disturbances—Channel relocation, riprap, channel clearing, diking, bridge abutments, and diversion.	Makes up steep riverb Mineral resources—S
Potential impacts to infrastructure and human safety.	Potentially unstable d
Flooding potential. Erosion potential.	Principal aquifer alon Fossils—Known to contain Pleistocene fossils regionally (e.g., musk ox; see Reheis 1987) Mineral resources—Sand, gravel, and placer gold.

Geologic History and Park Connections
Impaired troop movements during the battle
Mass wasting indicates slope instability sometime during the Holocene (the past 11,700 years)
Location of Indian encampment during the battle. Records past floodplain surfaces. Formed during the Pleistocene and range in age from 1.4 million to about 20,000 years old. The wide variety of clasts within the gravels attest to the wide variety of geologic units eroded by the ancient Little Bighorn River.

GRI Status (x / 270)



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URL’s For GRI Data Products

- GRI publications page:
  - http://www.nature.nps.gov/geology/inventory/gre_publications.cfm
- “IRMA” NPS Natural Resource Info Portal:
  - https://irma.nps.gov/App/Portal/Home
  - “IRMA” stands for Integrated Resource Management Applications

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GEOLOGIC RESOURCES

NPS » Explore Nature » Geologic Resources

- Abandoned Mineral Lands
- Coastal Geology
- Education & Outreach
- Energy & Minerals
- Geohazards
- Geologic Heritage Resources
  - Caves & Karst
  - Paleontology
  - Park Geology Tour
- Geoscientists-in-the-Parks
- Inventory & Monitoring
  - Geologic Resources Inventory
  - Geologic Monitoring
  - Soil Resources Inventory
- Land Restoration
- Planning & Permits
- Soils
- Who We Are

Geologic Resources Inventory Publications

The Geologic Resources Division produces the following three publications as part of the NPS Geologic Resources Inventory (GRI) Program:

Scoping Summaries (Learn more)
Geologic Reports (Learn more)
Geologic Maps (Learn more)

Geologic Resources Inventory Report Covers

Completed Products

Completed products are listed below, alphabetically by park. Blank spaces in the table indicate products that are not yet completed. Check back often for updates!

"GIS Format" links are to the NPS Integrated Resources Managment Application (IRMA) portal, where ZIP files for ESRI geodatabase, shapefile and/or coverage can be downloaded. Where available, Google Earth™ KMZ files are also downloadable from the GIS Format link(s).

A | B | C | D-E | F | G | H | I-J | K | L | M | N | O | P | R | S | T-U | V | W | Y-Z

Park	Scoping Summary	Geologic Report	Geologic Map
Mammoth Cave NP	PDF (232 KB)	*Full Report* Low Resolution PDF (15.7 MB) Print Body PDF (18.7 MB) Print Map Units Table PDF (141 KB) Print Park Map PDF (4.8 MB)	*GIS Format* Map Data *Printable PDF* Full Extent of Data and Legend (17.1 MB) Western Extent (8.3 MB) Eastern Extent (7.4 MB)
Manassas NBP	PDF (57 KB)	*Full Report* Low Resolution PDF (1.4 MB) Print Body PDF (27.3 MB) Print Map Units Table PDF (31 KB)	*GIS Format* Map Data *Printable PDF* Park and Vicinity (505 KB)
Manzanar NHS	PDF (81 KB)	*Full Report* Low Resolution PDF (2.8 MB)	*GIS Format* Map Data

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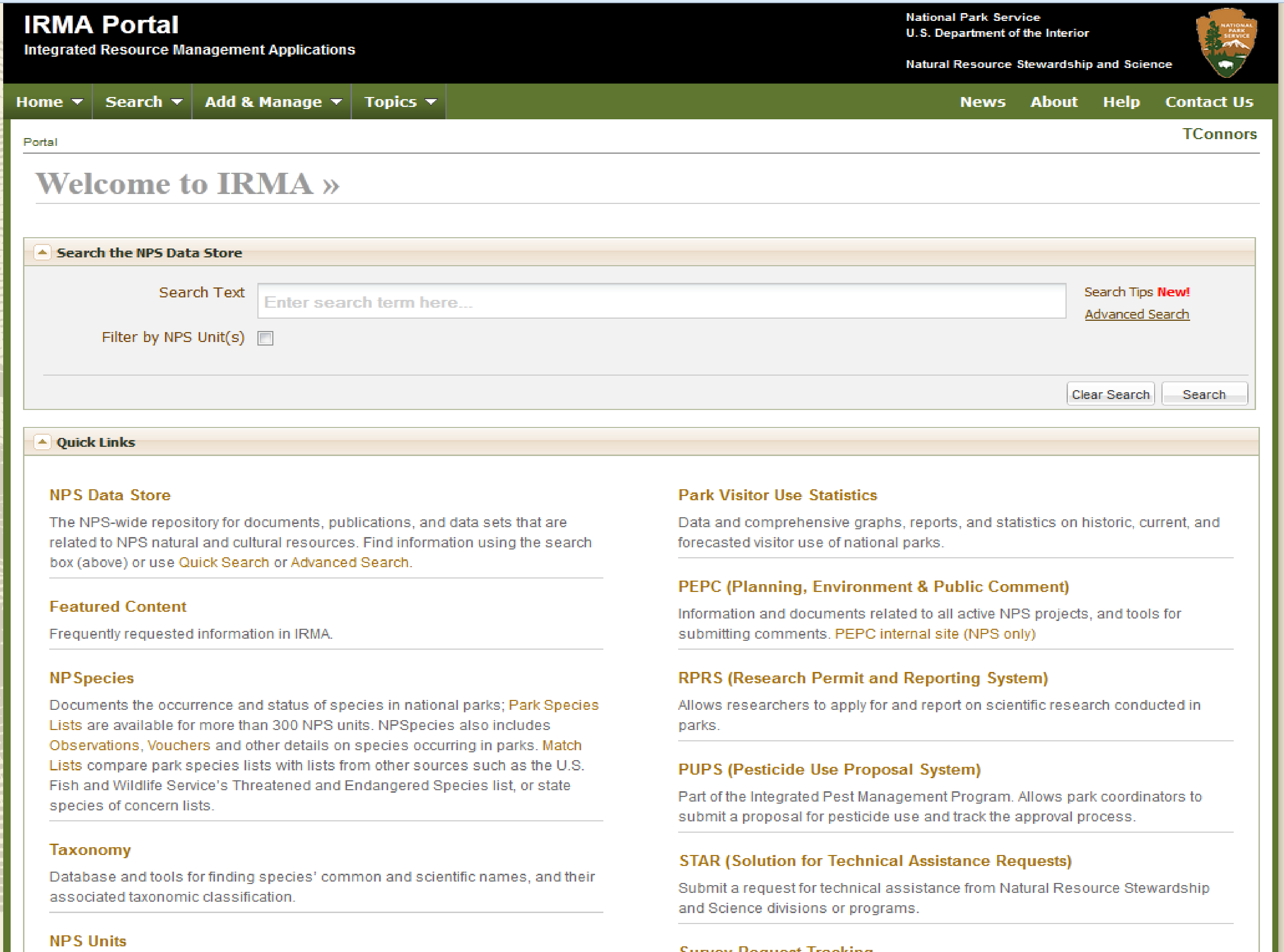
http://www.nature.nps.gov/geology/inventory/gre_publications.cfm



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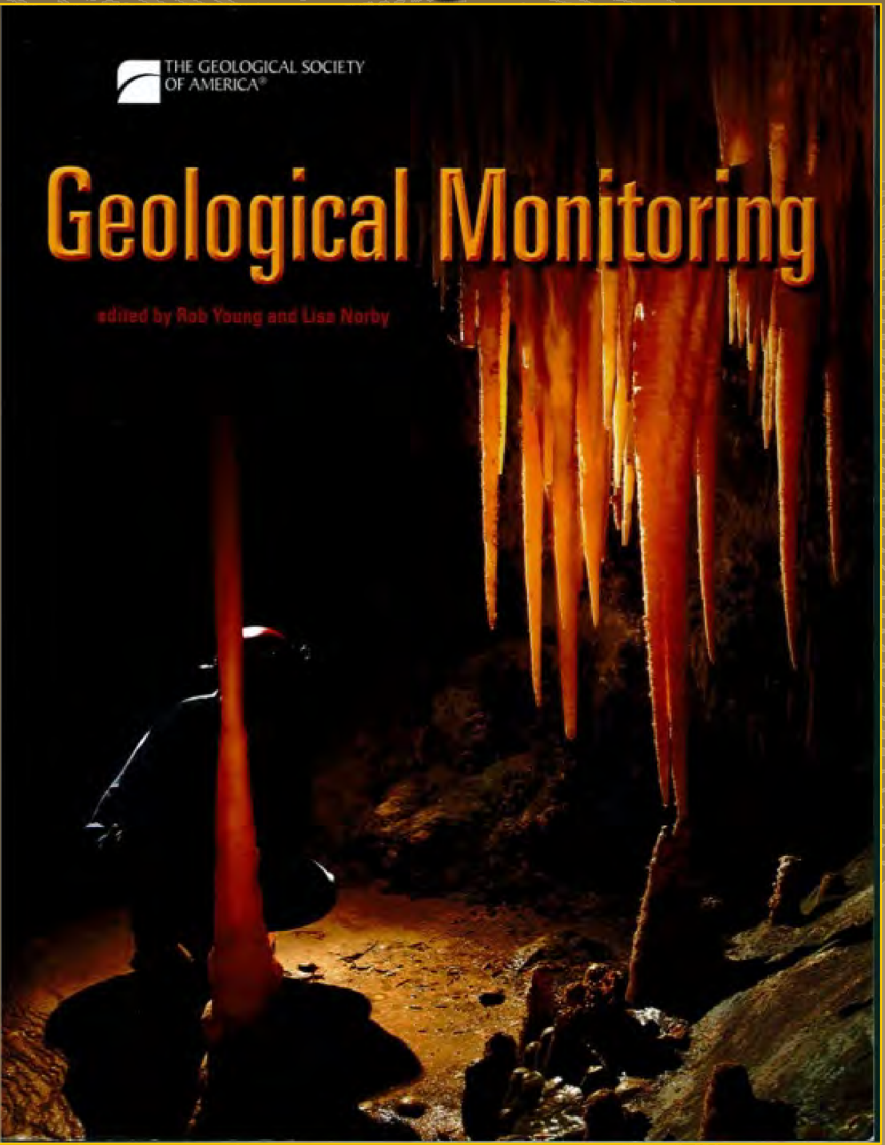
Geologic Resource Monitoring



1. *Aeolian features and processes* 1
Nicholas Lancaster

2. *Geological monitoring of caves and associated landscapes* 27
Rickard S. Toomey III

3. *Coastal features and processes* 47
David M. Bush and Rob Young

4. *Fluvial geomorphology: Monitoring stream systems in response to a changing environment* 69
Mark L. Lord, Dru Germanoski, and Nicholas E. Allmendinger

5. *Geothermal systems and monitoring hydrothermal features* 105
Henry P. Heasler, Cheryl Jaworowski, and Duncan Foley

6. *Glacier monitoring techniques* 141
Ronald D. Karpilo Jr.

7. *Marine features and processes* 163
David M. Bush

8. *Monitoring in situ paleontological resources* 189
Vincent L. Santucci, Jason P. Kenworthy, and Alison L. Mims

9. *Permafrost conditions and processes* 205
T.E. Osterkamp and M.T. Jorgenson

10. *Seismic monitoring* 229
Lawrence W. Braile

11. *Monitoring slope movements* 245
Gerald F. Wieczorek and James B. Snyder

12. *Volcano monitoring* 273
James G. Smith, Jonathan Dehn, Richard P. Hoblitt, Richard G. LaHusen, Jacob B. Lowenstern, Seth C. Moran, Lindsay McClelland, Kenneth A. McGee, Manuel Nathenson, Paul G. Okubo, John S. Pallister, Michael P. Poland, John A. Power, David J. Schneider, and Thomas W. Sisson

Geologic Resource Monitoring (continued)

Young, R. and L. Norby, editors. 2009. Geological Monitoring. Geological Society of America, Boulder, Colorado.

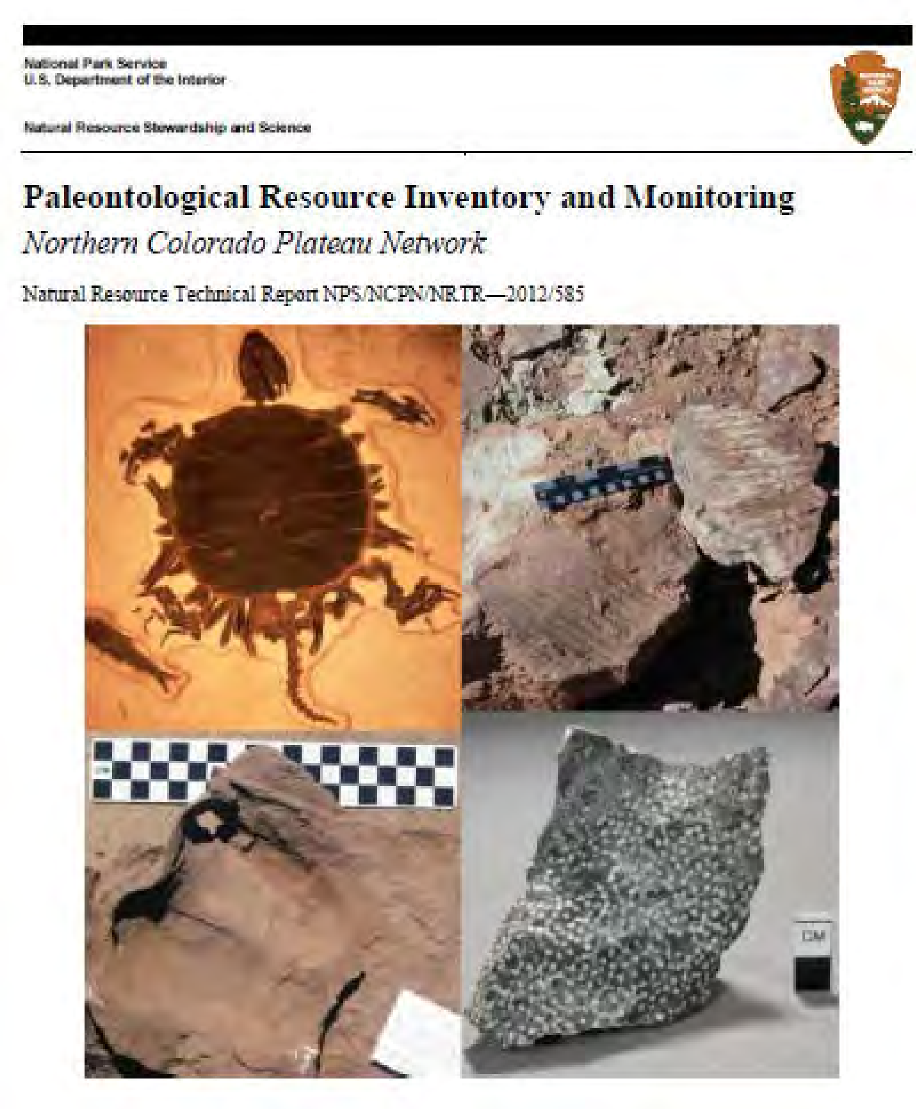
http://nature.nps.gov/geology/monitoring/files/geomon-00.pdf

Important Uses of Derived GRI information

- NPS Network-based Paleontological Resource Inventories
- NPS "Foundation" Resource Summaries
- NPS "State of the Parks" Summaries
- American Geosciences Institute "NPS theme" Geo-posters
- State based publications on NPS Lands (Utah, New Mexico)
- "Uses of Geologic Maps" publications
- Google Earth as visualization tool for digital geologic maps

NPS Network-Based Paleontological Resource Inventories

- Not initial part of NPS I&M mandate for geology**
- Largely completed because of Vince Santucci (and many others) dedication to NPS Paleontology
- **ALL** 32 NPS Networks have completed baseline Paleontological Resource Inventory
- Has led to identification of 238 NPS areas with known paleo resources



NPS "Foundation" Efforts: Arches National Park "WOW" statements

Geologic Resources Foundation Summary
Arches National Park
June 06, 2012

National Park Service
Natural Resource Stewardship and Science
Geologic Resources Division

NOTABLE GEOLOGIC RESOURCES

Landforms

Arches National Park preserves the greatest concentration of natural rock arches (>500) on Earth! Most arches are formed in three named geologic units (the Dewey Bridge Member of the Carmel Formation, the Slick Rock Member of the Entrada Sandstone, and the Moab Member of the Curtis Formation). The arches are a result of a unique geologic history. This history involves the formation of salt deposits (back in Middle Pennsylvanian to Late Triassic time; circa 300 million - 228 million years ago), and other sedimentary deposits (from Middle Pennsylvanian to Late Cretaceous time; circa 300 million to 70 million years ago), as well as the folding and faulting of these deposits in Tertiary time (circa 65 million to 2 million years ago) and finally to Quaternary (last 2 million years) erosion and salt dissolution. At Arches, the proper conditions for arch formation all coalesce. These include the following: presence of massive hard brittle sandstones jointed by faulting activity, resting on or containing soft layers or partings, and located near salt-cored anticlines experiencing dissolution, as well as a dry climate.

Arches National Park contains many "classic" or "iconic" geological sites. Among these are the following: Delicate Arch, Landscape Arch, The Windows Section, Balanced Rock, Park Avenue, Devils Garden, The Great Wall, Klondike Bluffs, Moab Fault, Fiery Furnace, Cache Valley, Elephant Butte Folds, Petrified Dunes and the La Sal Mountains viewpoint (though well south of Arches NP; it is an important viewshed feature). Geologically, each of these is quite significant and are protected and preserved as part of Arches NP.

NPS "Foundation" Efforts: Natural Bridges NM "WOW" statements

Geologic Resources Foundation Summary
Natural Bridges National Monument
June 06, 2012

National Park Service
Natural Resource Stewardship and Science
Geologic Resources Division

NOTABLE GEOLOGIC RESOURCES

Landforms

Natural Bridges National Monument was established in 1908 to protect three of the largest geologic "natural bridges" on earth (Sipapu, Kachina, and Owachomo bridges) and ruins in White Canyon and its tributaries that occur in Permian-aged (circa 270 million years ago) Cedar Mesa Sandstone. It is believed that these features have developed over the last 30,000 years. The Cedar Mesa Sandstone was deposited by immense windblown sand dunes that show massive cross-bedding today. Ancestral-Puebloan people likely occupied the area as well and left their traces in rock art in the sandstone walls.

NPS "Foundation" Efforts: Yellowstone NP "WOW" statements

Geologic Resources Foundation Summary
Yellowstone National Park
December 6, 2012

National Park Service
Natural Resource Stewardship and Science
Geologic Resources Division

NOTABLE GEOLOGIC RESOURCES

Geothermal Resources

Resource Description: Yellowstone National Park contains over half of the world's active geysers and over 10,000 hydrothermal features (hot springs, geysers, mudpots and steam vents). Yellowstone's hydrothermal system is a globally rare, composite natural resource that supports an array of recreational, economic, scientific, cultural, and natural heritage benefits. Yellowstone NP was founded to protect the extraordinary combination of natural processes that result in its hydrothermal system. The bottom of Yellowstone Lake contains rare geothermal features that are stalagmite-like, projecting from the lake floor.

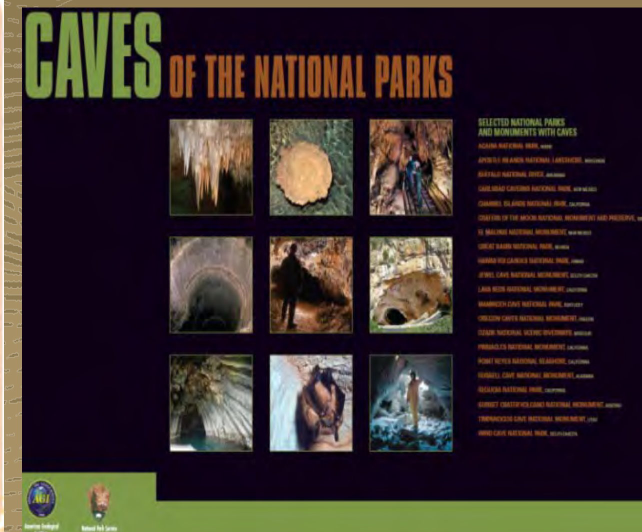
Landforms

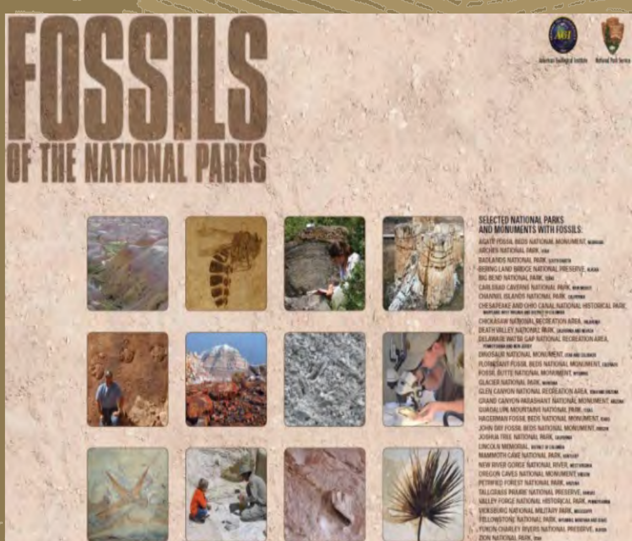
Resource Description: Yellowstone houses one of the World's largest active volcanoes. Yellowstone Lake is the surficial expression of a water filled collapse caldera that is a living testament to the volcanic activity present today. There are over 10,000 hydrothermal features (the heat from the magma powers the hydrothermal system). There are over 500 geysers. There have been over 80 lava flows since 640,000 years ago. Yellowstone NP historian Lee Whittlesey believes there are several hundred waterfalls in the park. There is also a natural bridge near Bay Bridge area, likely in volcanic rock. Obsidian Cliff is an outstanding outcrop of this type of volcanic deposit and is known for its value as a cultural resource in projectile points. There are outstanding examples of columnar jointed lava flows in many places of the park, noteworthy the Tower Junction area and Sheepeaters Cliff.

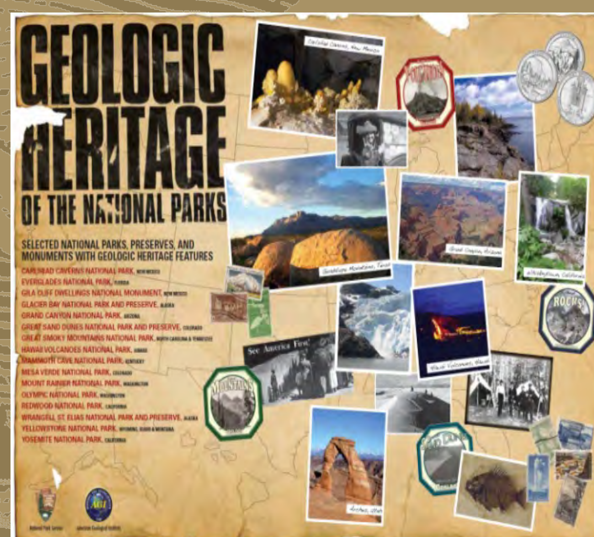
NPS State of the Parks: Black Canyon of the Gunnison NP

Geological Resources and Soils		A comprehensive Geologic Resource Inventory Map and Report was completed in 2005. A Soils Resource Inventory Map and Report is currently scheduled to be completed in 2014. No dedicated hazards mapping or monitoring is currently in place or scheduled.
Geological Resources Paleontology		Cursory surveys have already indicated that paleontological resources in the park are significant. The potential for future significant discoveries is very high. We have increased discovery and documentation of known paleontological localities by over 400% in the last decade. Inventory efforts will continue with similar results expected.

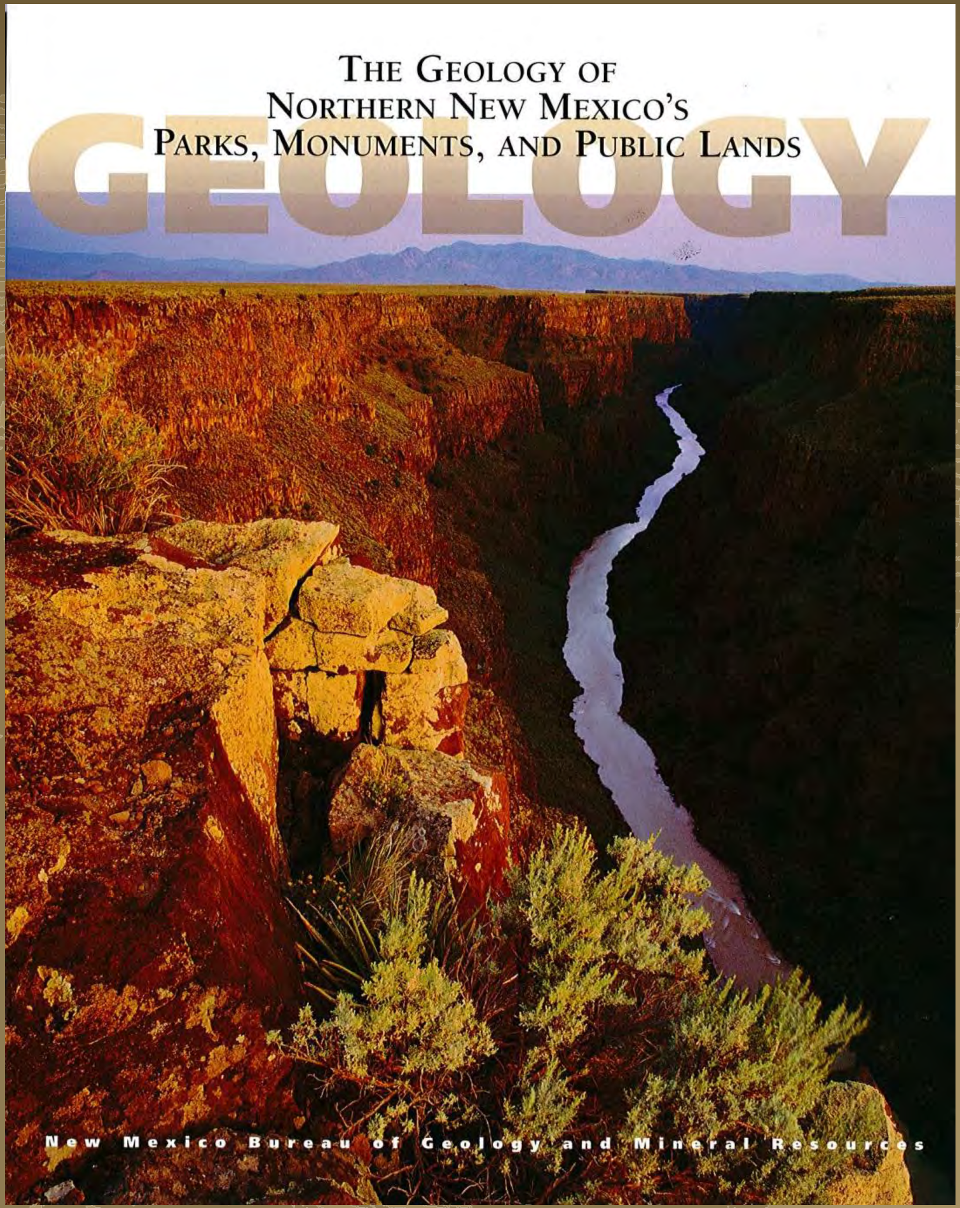
American Geosciences Institute "NPS theme" Geo-posters

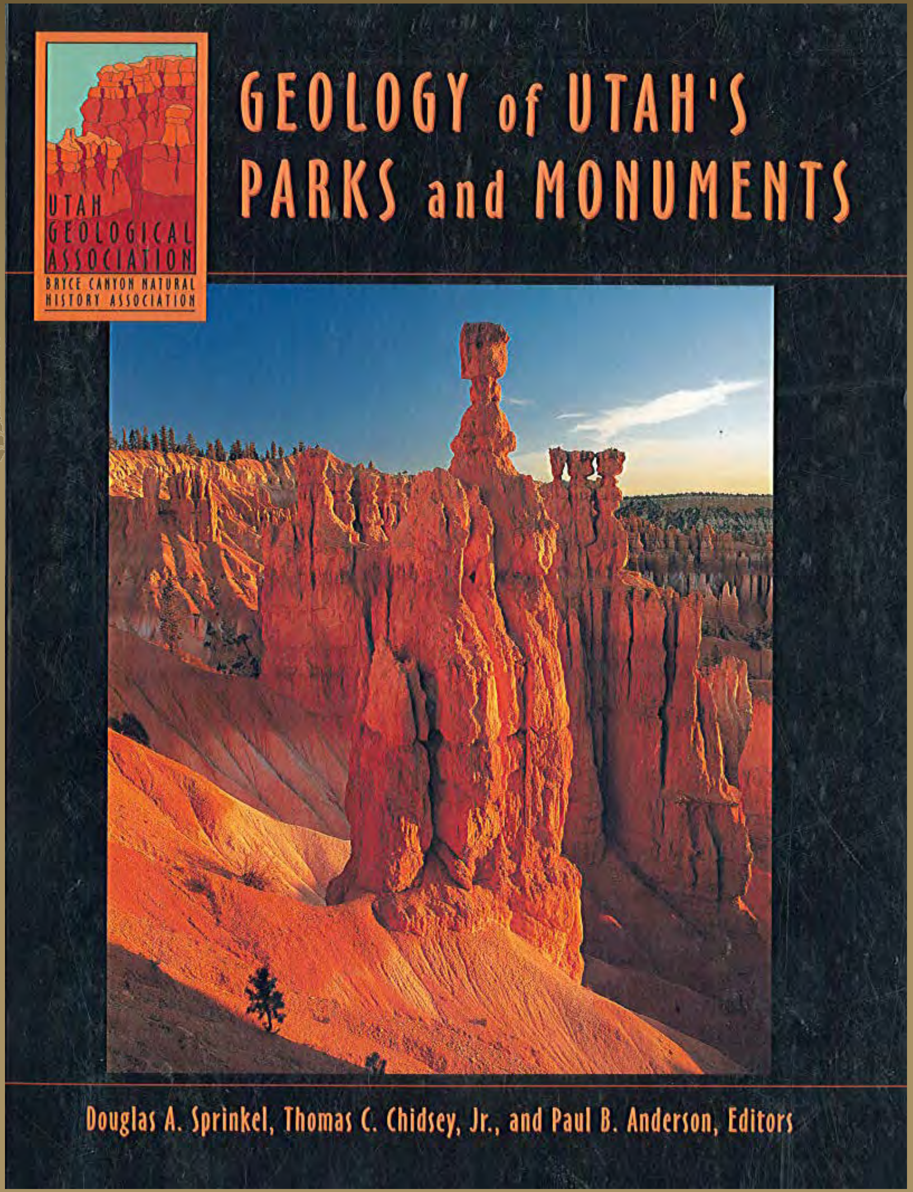






State based publications on NPS Lands (Utah, New Mexico)





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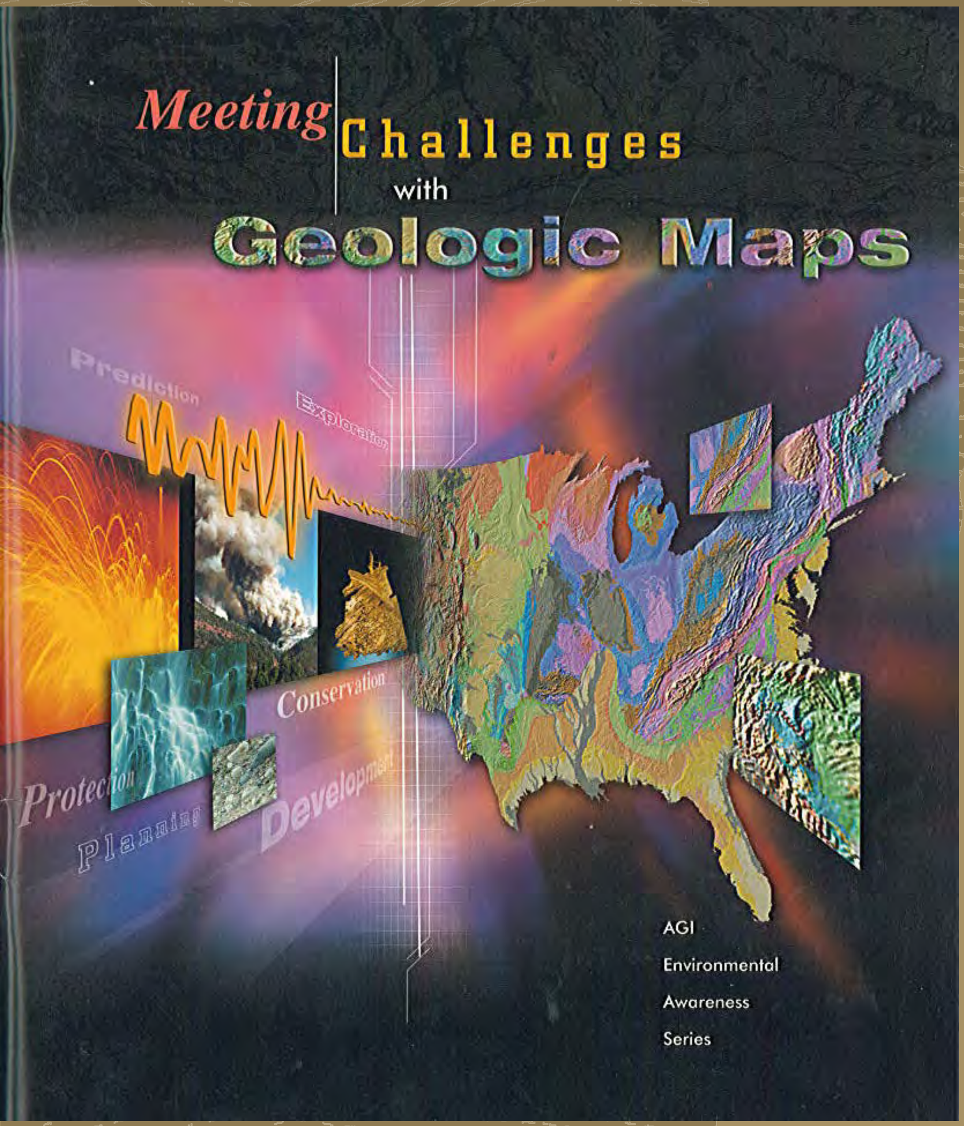
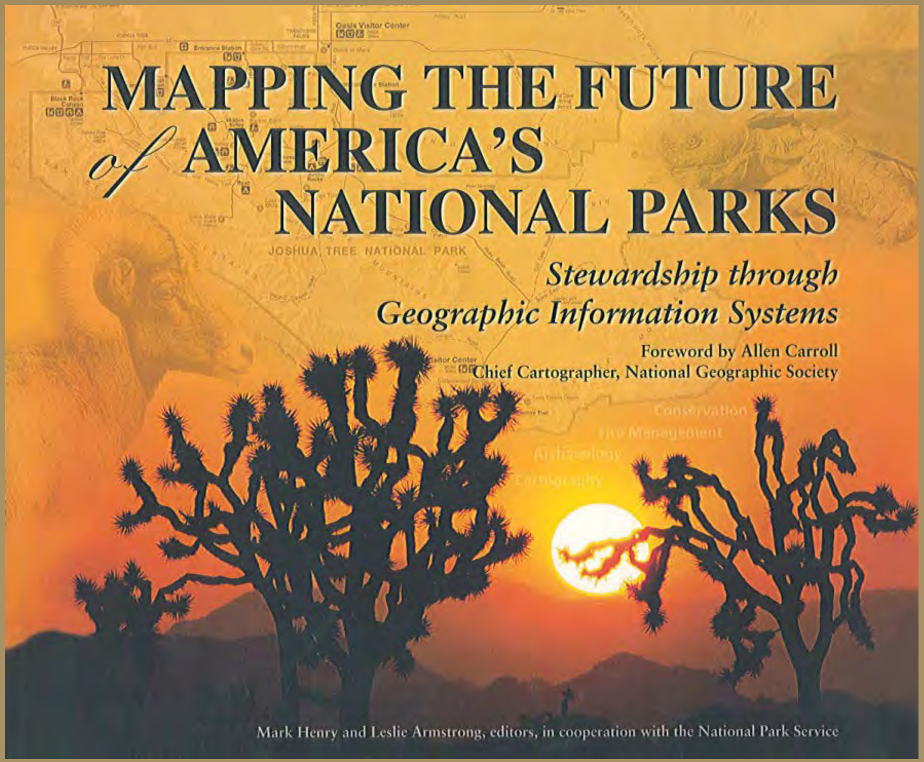
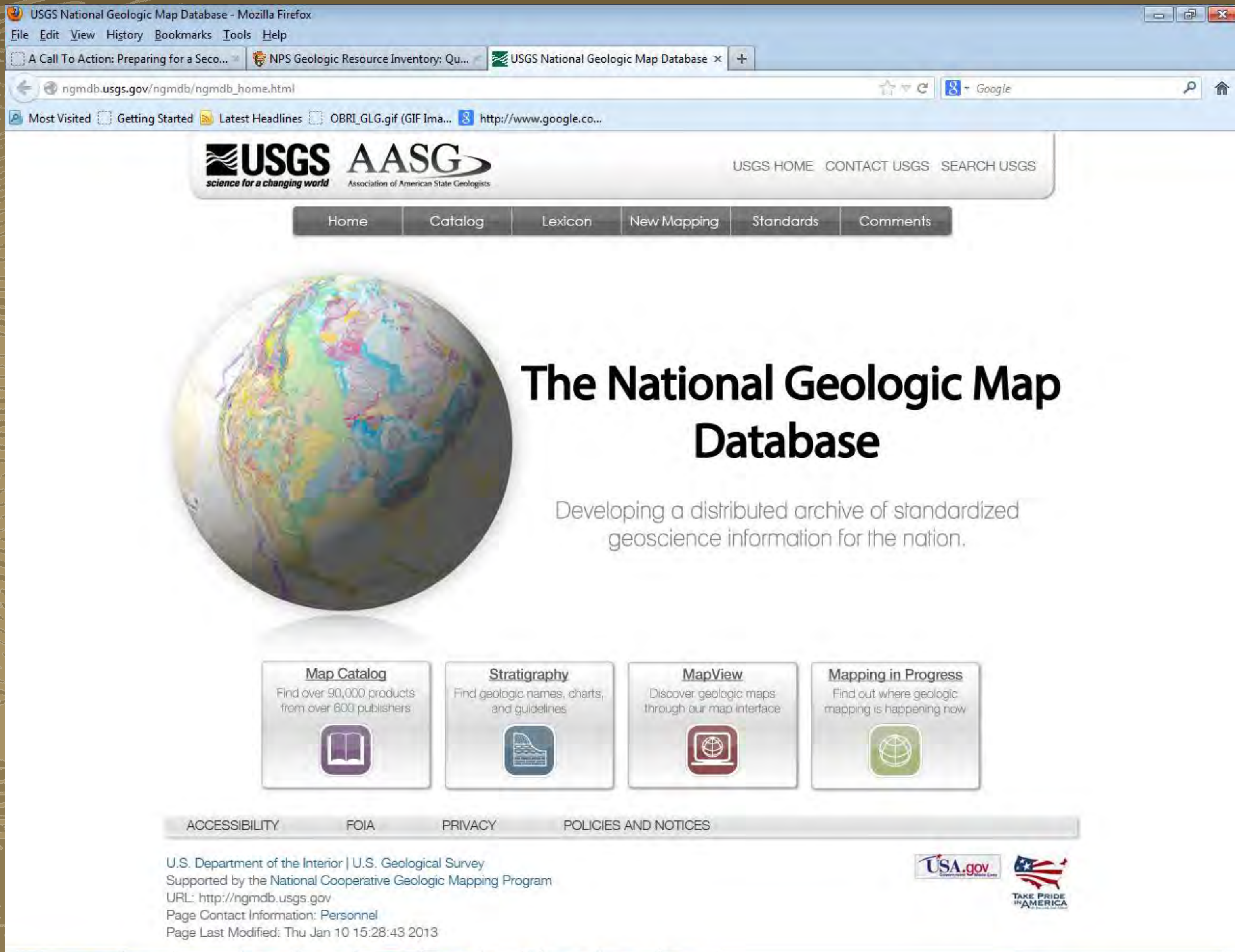
"Uses of Geologic Maps" publications



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NPS Geologic Resources Inventory Program. 2006. Unpublished Digital Geologic Map of the Dinosaur Quarry Quadrangle, Utah (NPS, GRD, GRI, DINO, DIQU digital map) adapted from the U.S. Geological Survey Geologic Quadrangle map by Rowley, Kinney and Hansen (1979). NPS Geologic Resources Inventory Program. Lakewood, CO. Geospatial Dataset-1038937.

Geospatial Dataset

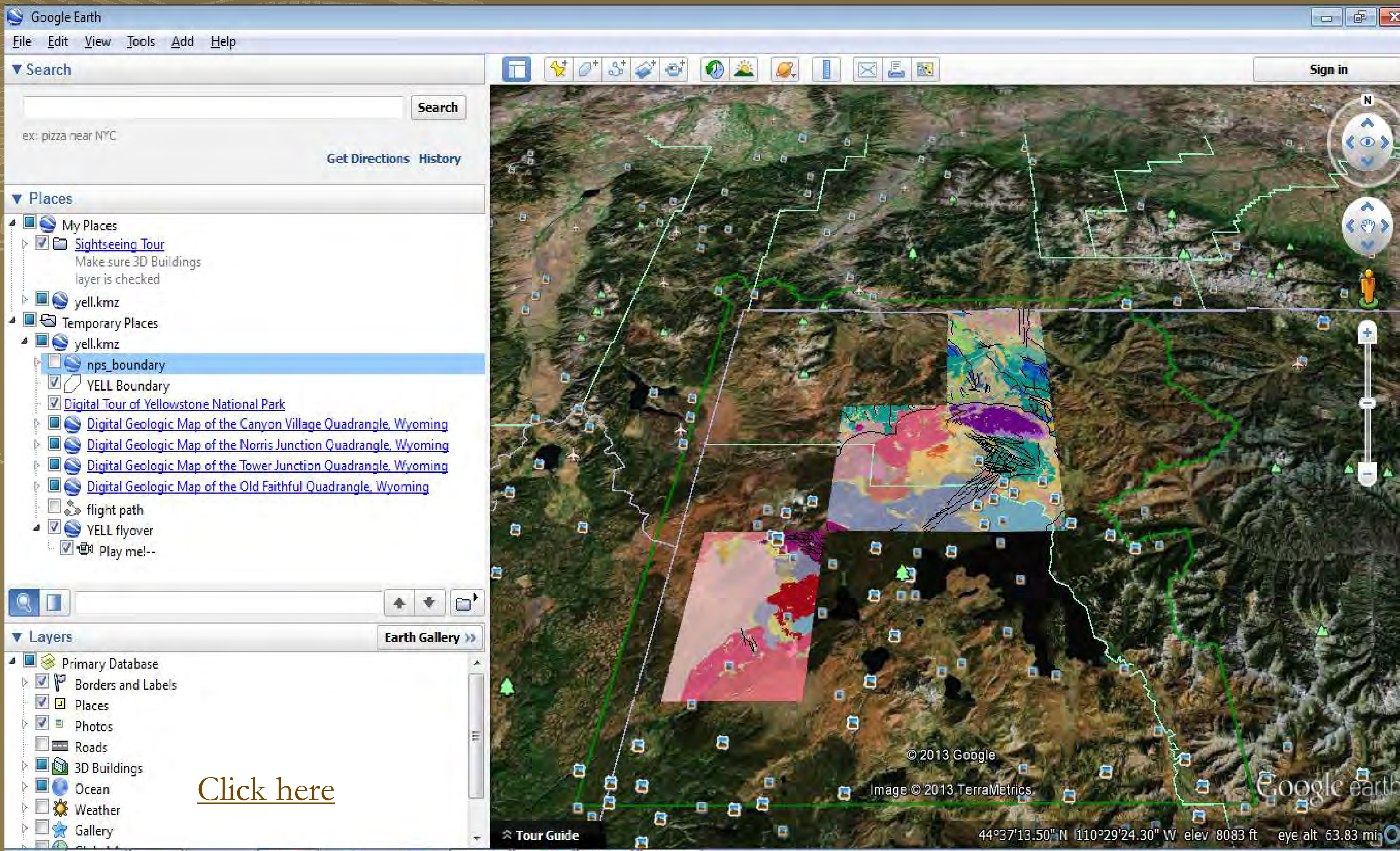
Reference Code: 1038937
Reference Status as of 01/17/2012: Active
Visibility: Public

Core Information

Geospatial Dataset

Title	Unpublished Digital Geologic Map of the Dinosaur Quarry Quadrangle, Utah (NPS, GRD, GRI, DINO, DIQU digital map) adapted from the U.S. Geological Survey Geologic Quadrangle map by Rowley, Kinney and Hansen (1979)
Brief Description	-
Date of Issue/Release	February 06, 2006
Content Begin Date	-
Content End Date	-
Abstract / Full Description	The Unpublished Digital Geologic Map of the Dinosaur Quarry Quadrangle, Utah is comprised of GIS data layers, two ancillary GIS tables, a Windows Help File with ancillary map text, figures and tables, GIS data layer and table FGDC metadata and ArcView 3.X legend (.AVL) files. The data were completed as a component of the Geologic Resources Evaluation (GRE) program, a National Park Service (NPS) Inventory and Monitoring (I&M) funded program that is administered by the NPS Geologic Resources Division (GRD). All GIS and ancillary tables were produced as per the NPS GIS-Geology Coverage/Shapefile Data Model (available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.htm). The GIS data is available as coverage and table export (.E00) files, and as a shapefile (.SHP) and DBASEIV (.DBF) table files. The GIS data projection is NAD83, UTM Zone 12N. That data is within the area of interest of Dinosaur National Monument.
Purpose	The data are intended to assist NPS personnel in the protection and management of Dinosaur National Monument.
Version	1st
Generic Code	DINO
Location Description	Lakewood, CO
Notes	The data layers (feature classes) that comprise the Unpublished Digital Geologic Map of the Dinosaur Quarry Quadrangle, Utah include: DIQUGLG (geologic units and contacts), DIQUFLD (geologic folds), DIQUFLT (geologic faults), DIQUATD (geologic attitude observation points), DIQUMIN (mine and mine related point features), DIQUSEC (geologic cross section lines) and DIQUJLN (geologic linear joints). There are three additional ancillary map components, the Geologic Unit Information (DINOGLG1) Table, the Source Map Information (DINOMAP) Table and the Map Help File (DINOGLG.HLP). Refer to the NPS GIS-Geology

Yellowstone NP Geology & Google Earth



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